Space Technology Research Grants

Stability Analysis of Spacecraft Motion in the Vicinity of Asteroids

Completed Technology Project (2013 - 2017)

Project Introduction

The objective of my proposal is to determine the stability of a spacecraft when in the vicinity of an asteroid. Orbiting an asteroid is a difficult task. The unique shapes in which asteroids are formed cause the gravity around them to be non-uniform. This causes perturbations in the movement of a spacecraft around an asteroid. Solar radiation pressure can also alter the orbit of a spacecraft around an asteroid. With multiple perturbations on a spacecraft, orbiting an asteroid can become unstable over time. This instability could lead to the spacecraft escaping from the body or crashing into the asteroid. By determining an algorithm that can define the stability of a spacecraft around an asteroid, safe and stable orbits can be found for an operational spacecraft. In order to achieve a greater understanding of the stability of a spacecraft in the vicinity of an asteroid, the dynamics of the spacecraft around the asteroid must be well understood. All perturbing forces that will act on a spacecraft orbiting an asteroid must be accurately modeled. This includes mathematical modeling of the gravity around the asteroid due to its non-spherical shape, third-body dynamics from the sun, and solar radiation pressure. Rotation of the spacecraft and asteroid will also be part of accurately modeling the dynamics of this system. The largest portion of the research will be focused on determining what the proper definition of stability is for the spacecraft. Stability of a system can be defined in various ways using multiple stability analysis methods. Because these differing methods often result in subtle differences that have significant consequences, the determination of stability for a spacecraft mission can be difficult to find using mathematical definitions that apply to practical needs of the mission. Therefore finding a meaningful mathematical definition for stability that can be applied to an operation mission will be the core of my research. Lyapunov stability will used as a preliminary tool to give insight into more complex methods of determining stability. This includes the stability methods such as Lyapunov characteristic exponents, FLI, and MEGNO. For future missions to asteroids this allows the spacecraft to orbit naturally without as many correctional maneuvers. Also, understanding the stability of a spacecraft around an asteroid will give future missions more confidence in opting to orbit in close proximity of the asteroid, which will allow for more science to be obtained. Gaining knowledge on the behavior of a spacecraft around an asteroid will help define go to stable orbits that are dependable for the spacecraft to stay in for long periods of time. By better understanding the dynamics and stability of spacecraft motion around an asteroid, a spacecraft will be able to achieve better understanding of the asteroids size, shape, rotation, gravity field, and mass. Therefore it encourages a relationship where a better understanding of the dynamics of the spacecraft causes more science to be found; and with better science comes more refined models that improve the dynamics of the orbiting spacecraft. This information can be used for both scientific human missions and resource extraction missions to asteroids. NASA plans on landing humans on an asteroid with the next generation of crewed space flight vehicles. With human life on the line, knowledge of how the crew transport vehicle will behave

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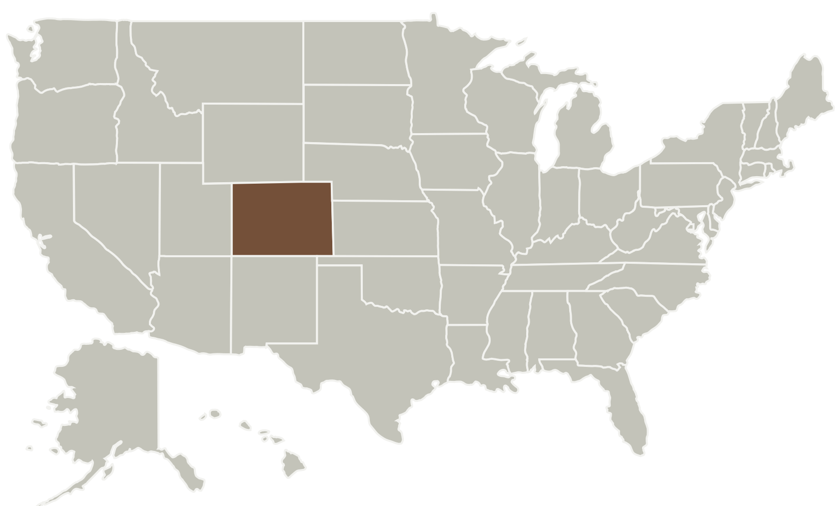
orbiting the asteroid needs to be well known.

Anticipated Benefits

For future missions to asteroids this allows the spacecraft to orbit naturally without as many correctional maneuvers. Also, understanding the stability of a spacecraft around an asteroid will give future missions more confidence in opting to orbit in close proximity of the asteroid, which will allow for more science to be obtained. Gaining knowledge on the behavior of a spacecraft around an asteroid will help define go tostable orbits that are dependable for the spacecraft to stay in for long periods of time. By better understanding the dynamics and stability of spacecraft motion around an asteroid, a spacecraft will be able to achieve better understanding of the asteroids size, shape, rotation, gravity field, and mass. Therefore it encourages a relationship where a better understanding of the dynamics of the spacecraft causes more science to be found; and with better science comes more refined models that improve the dynamics of the orbiting spacecraft. This information can be used for both scientific human missions and resource extraction missions to asteroids. NASA plans on landing humans on an asteroid with the next generation of crewed space flight vehicles. With human life on the line, knowledge of how the crew transport vehicle will behave orbiting the asteroid needs to be well known.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Daniel Scheeres

Co-Investigator:

Samantha M Rieger

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Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado

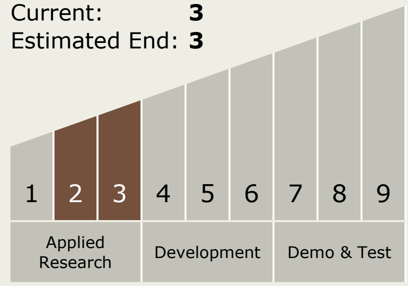
Primary U.S. Work Locations
Colorado

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  - └ TX17.2 Navigation Technologies
    - └ TX17.2.6 Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination

Target Destination

Others Inside the Solar System